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# Multimodality Imaging in Renal Infections-A Pictorial Essay

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***Abstract :*** *Urinary tract infections is among the most frequently reported infections accounting for patient morbidity. Diagnostic imaging plays an important role in the evaluation of patients with urinary tract infections to guide appropriate medical or surgical therapy. Various imaging modalities useful in the diagnosis and characterisation of urinary tract infections include conventional abdominal radiography, ultrasonography, intravenous urography, computed tomography and magnetic resonance imaging. This pictorial essay highlights on the potential benefits and limitations of various imaging modlaities in diagnosis and characterisation of various renal infections namely acute bacterial pyelonephritis, renal and perinephric abscess, pyonephrosis, chronic pyelonephritis ,emphysematous pyelonephritis, xanthogranulomatous pyelonephritis ,renal tuberculosis, fungal infections and renal disease associated with HIV/AIDS. The various imaging findings including imaging of various complications are illustrated with possible advantages and pitfalls of various imaging modalities in the diagnosis of various infections.*

***Keywords:*** *Emphysematous pyelonephritis, Pyelonephritis, Renal abscess, Renal tuberculosis, Xanthogranulomatous pyelonephritis*

## I. Introduction

Urinary tract infections (UTIs) are the most commonly reported bacterial infection.150 million people were infected with UTI per annum worldwide. Diagnostic imaging is generally indicated for patients with complicated UTIs where radiologic evaluation can be useful in directing appropriate medical or surgical therapy, thereby preventing unfavorable or potentially catastrophic outcomes.

The available imaging modalities include ultrasound (US), intravenous urography (IVU), computed tomography (CT) with or without CT urography, and magnetic resonance imaging (MRI), each with their own potential benefits and limitations. In this pictorial essay, we will review the imaging findings of upper tract UTIs found primarily in the adult population including acute pyelonephritis, renal and perirenal abscess, pyonephrosis, chronic pyelonephritis, emphysematous pyelonephritis, xanthogranulomatous pyelonephritis (XGPN), renal tuberculosis, fungal infections and renal disease associated with HIV/AIDS.

While the clinical presentation will often narrow the differential diagnosis to an infectious etiology, it is important to recognize alternate entities that may appear similarly on radiologic imaging.. Understanding the role of imaging in suspected renal infections and recognizing their imaging characteristics will hopefully promote the judicious use of radiologic studies and improve outcomes for patients with complicated renal infections.

## II. Acute Pyelonephritis

The basic pathogenetic process is that of a tubulointerstitial nephritis as the glomeruli are resistant to infection till later stages[1]. The hallmark of the disease is absence of nephritic or nephrotic syndrome. Only the tubular function is affected which may be manifested in the form of impaired urinary concentration, polyuria, nocturia and salt wasting.

### 2.1 Clinical Presentation and Pathogenesis

The patient typically present with abrupt onset of chills, fever and flank pain. Patients may also present with non specific gastrointestinal symptoms like abdominal pain, vomiting and diarrhoea. The ascent of infection occurs even in the absence of reflux disease . Most frequent etiological agent is gram negative organisms. Important virulence factors implicated include fimbriae and endotoxins . Endotoxins inhibit ureteric peristalsis , causing functional obstruction and compromising the forward flow of urine which is a protective mechanism against urinary tract infections[1]

Initially the infection begins as an ureteropyelitis with continuing retrograde ascent into the renal tubules and papilla.

### 2.2 Role of diagnostic imaging

Imaging helps to assist in the diagnosis of pyelonephritis, especially in patients who do not respond to vigorous antibiotic treatment in 72 hours. It also helps to look for structural abnormalities of the urinary tract

which can act as an inciting event for the disease. Imaging can also help to assess severity of infection and to direct further therapy or intervention. The extent of organ damage can also be evaluated with various imaging modalities.

Various imaging modalities ranging from conventional abdominal radiography, intravenous urogram, ultrasonography with color doppler imaging, multidetector Computed tomogram with CT Urogram and Magnetic Resonance Imaging can aid in the diagnosis of pyelonephritis[2]

**2.2.1 Abdominal Radiography**

Abdominal radiography although rarely used these days is an inexpensive and rapid modality to diagnose pyelonephritis. Despite its lack of senstivity abdominal radiographs are useful to detect calcification and gas. However it has been overtaken by MDCT due to its improved sensitivity[2]

**2.2.2 Excretory Urography**

Before the advent of MDCT this was the imaging modality of choice to delineate the collecting system anatomy and also to provide an overview of the urothelial system from kidneys to bladder. The imaging features to suggest a possibility of pyelonephritis on an excretory urogram include enlargement of the involved kidney, striated or delayed nephrogram, delayed calyceal appearance and dilatation or effacement of calyceal system[2]. Despite its easy availability, the excretory urogram has its limitations in characterizing the parenchymal details and in delineating the renal and perinephric spread of the disease process.

**2.2.3 Ultrasonography**

Ultrasonography is an easily available imaging modality and has better sensitivity when compared to the other conventional imaging modalities. The various gray scale imaging features that point towards a diagnosis of acute pyelonephritis include enlargement of the involved kidney with loss of renal sinus fat due to edema(Figure 1) There is a change in the renal echopattern and the involved kidney can appear either hyperechoeic or hypoechoeic. There is associated loss of corticomedullary differentiation[3]. Color doppler imaging reveals areas of hypoperfusion in the involved kidney(Figure 2). Ultrasonography can also help in diagnosing associated urinary tract anomalies and presence of hydronephrosis in the setting of associated obstruction. Presence of abscess formation and papillary necrosis (Figure 3) can also be detected on gray scale imaging

The urinary bladder must be also be evaluated in the setting of pyelonephritis to look for residual urine volume, presence of bladder wall thickening and calculus. Ultrasonography is also useful in detecting prostatic enlargement.Ultrasound has its limitations in detection of calcification/gas, visualisation of microabscess and identification of early perinephric extension.

**2.2.4 Computed Tomography (CT)**

Computed Tomography is the imaging modality of choice in the diagnosis of pyelonephritis[2,4,5,6]. Unenhanced CT helps in the detection of calculi, gas, renal enlargement or mass formation and features of urinary obstruction(Figure 4)Contrast enhanced CT remains the gold standard in the diagnosis. The protocol followed in our institution includes imaging at 50-90 sec after injection of contrast. This is done to take advantage of the nephrographic phase in which normal kidney is homogenously enhanced.

The various features on contrast enhanced images include one or more wedge or streaky zones of lesser enhancement extending from papilla to cortex(Figure 5,6). This differential enhancement is contributed by various factors namely tubular obstruction by inflammatory debris, interstitial oedema and vasospasm which tend to decrease the flow of contrast through tubules[2,5,6] This mechanism also explains the delayed and persistent enhancement seen 3-6 hrs after contrast administration and the prolonged accumulation of contrast agent .Overtime this differential enhancement becomes less distinct and with prompt and adequate treatment may even normalize.

The presence of round peripheral hypo attenuating renal lesions in the clinical setting of pyelonephritis indicate hematogenous seedling of infection. There are various secondary signs of pyelonephrits namely focal or globular enlargement of kidney, perinephric fat stranding, thickening of Gerota's fascia and abscess formation. Complications of pyelonephritis can also be detected by CT. Abscess formation, papillary necrosis(Figure 7) and obstruction with collecting system dilatation(Figure 8) can be detected.

**2.2.5 Magnetic Resonance Imaging (MRI)**

MR imaging of renal infections is especially useful in patients in whom radiation exposure is contraindicated, for example pregnant patients. The MR imaging findings are similar to those of CT and include the presence of renal edema, hemorrhage, renal enlargement, abscesses and perinephric fluid collections.

## III. Renal And Perinephric Abscess

Untreated or inadequately treated pyelonephritis can lead to parenchymal necrosis that eventually leads to abscess formation[2,5,6,7] The patients at risk of abscess formation include those with diabetes mellitus, immunocompromised individuals, those with chronic debilitating illnesses, patients with associated urinary tract obstruction and intravenous drug abusers[2,5,6]

On ultrasonography, renal abscesses appear typically hypoechoeic with through transmission with associated mobile debris and occasional air pockets(Figure 9) On color doppler imaging renal abscesses lack internal flow[2,3] Ultrasonography is inferior to CT in determining the presence and extent of perinephric extension(Figure 10,11). However it is an excellent modality for follow-up imaging to look for response to treatment and as a guide for percutaneous drainage.

Renal abscesses tend to be solitary and decompress into perinephric space or collecting system. Renal abscesses can be managed by medical treatment hence reserving interventional treatment for large collections or patients with clinical deterioration[7] Prompt diagnosis is an important factor in the outcome of renal and perinephric abscesses.

## IV. Pyonephrosis

Pyonephrosis implies an infected and obstructed collecting system, which frequently is enlarged. In the adult population, the obstruction may arise from a variety of disease processes such as calculi, tumor, complications from pyelonephritis (sloughed papilla) or strictures. Early diagnosis is crucial because direct immediate intervention is required in these patients[2,4]

The ultrasonographic features include dilatation of the pelvicalyceal system, echogenic collecting system debris, fluid-fluid levels within the collecting system, and occasionally the incomplete (dirty) echoes of collecting system gas[3,4] CT demonstrates thickening of the renal pelvic wall (>2 mm), parenchymal or perinephric inflammatory changes, dilatation and obstruction of the collecting system, with fluid of higher attenuation value and layering of contrast material above or anterior to the purulent fluid on excretory studies[2,5,6] (Figure 12). A caveat in CT evaluation is that it is often difficult to distinguish simple hydronephrosis from pyonephrosis on the basis of fluid attenuation measurements.

## V. Chronic Pyelonephritis

Chronic pyelonephritis represents chronic infection due to multiple recurrent infections or stable changes from a remote single infection[1,2] The imaging findings are characterized by renal scarring, atrophy and cortical thinning(Figure 13,14)There can be associated hypertrophy of residual normal tissue which may mimic a mass lesion, presence of calyceal clubbing secondary to retraction of the papilla from overlying scar, thickening and dilatation of the calyceal system and overall renal asymmetry[2,3,4,5,6]

## VI. Emphysematous Pyelonephritis

Emphysematous pyelonephritis is a life-threatening necrotizing infection of the kidneys and collecting system characterized by gas formation. The disease is associated with patients having poorly controlled diabetes in majority of the cases. Other patients at risk include those who are either immunocompromised or have associated urinary tract obstruction secondary to urolithiasis, neoplasm or sloughed papilla[1,2]The most commonly identified organisms are *E coli, Klebsiella pneumonia* and *Proteus mirabilis.* Due to its rapidly progressive course and high mortality rate, early diagnosis and therapeutic intervention is mandatory.

The imaging features of emphysematous pyelonephritis is quite classical of the disease. On conventional abdominal radiography there is presence of mottled gas within the renal fossa(Figure 15) Features indicative of perinephric extension include crescentic collections of gas within the Gerota's fascia

Ultrasonography demonstrates an enlarged kidney with nondependent echoes within the renal parenchyma or collecting system indicating the presence of air. The echogenic foci demonstrate “dirty shadowing” that help distinguish the entity from renal stone disease[2,3,4] However ultrasonography is inferior in evaluating the extent of the disease and categorizing the type of the disease .

CT is the imaging modality of choice for evaluating patients with emphysematous pyelonephritis. It helps in identifying the type of emphysematous pyelonephritis. The imaging findings on CT include parenchymal enlargement and destruction, small bubbly or linear streaks of gas, presence of fluid collections, gas-fluid levels and focal tissue necrosis with or without abscess formation[2,4,5,6]

Emphysematous pyelonephritis is classified into two types based on imaging features and prognostic determinants by Wan et al. Type 1 emphysematous pyelonephritis is characterized by destruction of the renal parenchyma manifesting as streaky or mottled areas of gas. Intra- or extrarenal fluid collections are charcteristically absent. This type of emphysematous pyelonephritis has a more severe downhill course with higher reported mortality rates of 69%. In contrast, type 2 emphysematous pyelonephritis is characterized by

renal or perirenal fluid collections that are associated with bubbly or loculated gas or by gas within the collecting system. This type has a better clinical outcome with a lower reported mortality rate of 18%[2,5]

In addition to the above classification the Huang-Tseng CT classification system[8] is also described which classifies Emphysematous pyelonephritis into four classes[8]

Class 1: gas in collecting system only(Figure 16)

Class 2: gas in renal parenchyma only (without extrarenal extension) (Figure 17,18)

Class 3: gas in renal parenchyma with extrarenal extension

Class 3a: extension of gas or abscess to perinephric space(Figure 19)

Class 3b: extension of gas or abscess to pararenal space(Figure 20)

Class 4: bilateral emphysematous pyelonephritis or solitary kidney with emphysematous pyelonephritis

Conservative treatment in the form of percutaneous drainage with antibiotics has been the gold standard protocol in management of patients with emphysematous pyelonephritis belonging to Class 1 and 2(Figure 21) Conservative management is also followed for the Class 3 and 4 patients in the presence of fewer than two risk factors viz., thrombocytopenia, elevated serum creatinine levels, altered sensorium and shock. In those patients with more than two risk factors in the Class 3 and 4 surgical treatment in the form of nephrectomy is the treatment of choice[8]

## VII. Xanthogranulomatous Pyelonephritis

Xanthogranulomatous pyelonephritis is a chronic destructive granulomatous process resulting from an atypical, incomplete immune response to subacute bacterial infection. It is frequently associated with patients having diabetes mellitus and has an increased incidence in middle aged female patients[2,4]The symptomatology is often nonspecific with low-grade fever and malaise, although flank pain and hematuria may indicate involvement of the urinary tract and suggest further imaging.The disease process is induced by recurrent bacterial urinary tract infection in which the renal parenchyma is replaced by lipid-laden foamy macrophages. Xanthogranulomatous pyelonephritis is seen in association with a renal pelvic calculus. The most common organisms implicated are *P mirabilis* and *E coli*[2,4,5]

The use of conventional abdominal radiography has almost become obsolete with the advent of CT. However, the findings suggesting a possibility of Xanthogranulomatous pyelonephritis are a large staghorn calculus , enlargement of the renal outline and obscuration of the ipsilateral psoas margin. On excretory urography, ipsilateral kidney shows a decrease in renal function with no excretion despite delayed imaging. However this finding is non specific and can be seen with a number of other conditions[2,4,6]

Ultrasonography demonstrates an enlarged kidney with a renal pelvic staghorn calculus. There is an associated loss of normal renal architecture however a discrete inflammatory mass is uncommon[2,3] (Figure 22) CT is often required to ascertain the diagnosis despite the characteristic appearance on ultrasound.

CT remains the mainstay of diagnosis and supplements the findings on ultrasonography . The findings suggestive of xanthogranulomatous pyelonephritis include a nonfunctioning enlarged kidney with a large renal pelvic calculus(Figure 23), expanded calyces(Figure24) and perinephric fat inflammation. Patients can also have extrarenal extension of the disease process in the form of psoas abscess and fistula formation (cutaneous or colonic) [2,4,5,6]Some of the less common atypical presentations of the disease include focal form of the disease, renal atrophy rather than enlargement, absence of renal calculi and presence of gas.

## VIII. Urinary Tract Tuberculosis

Tuberculosis is the commonest worldwide cause of mortality from infectious diseases with approximately 95% of cases occuring in developing countries**.** There is a resurgence of tuberculosis due to the HIV pandemic and the multi drug-resistant strains of the TB Bacilli**.** The genitourinary tract is the most common site of extra-pulmonary TB seen involved in approximately 14-41% of the cases[9]

The kidney is the most common site of involvement in the urinary tract. There is an increased incidence in patients with HIV/AIDS. The disease usually affects adults in the second to the fourth decade and is quite rare in children. There is often a long latent period ranging from 5 to 40 years between the original pulmonary infection and the appearance of clinical renal disease.

The disease has an insidious onset with atypical presentations leading to difficulty and delay in diagnosis. The patients present with frequent voiding, dysuria, pyuria , flank or abdominal pain and microscopic or macroscopic hematuria. Systemic symptoms of fever, weight loss and anorexia seen in pulmonary tuberculosis are less common [2,9]

Urine analysis demonstrates hematuria and culture-negative pyuria. Acid fast bacilli are demonstrated in 80-90% of the cases. Urine culture requires 6-8 weeks for diagnosis and hence is superseeded with polymerase chain reaction (PCR) for *Mycobacterium tuberculosis*[4,9] Only 36.5% of patients with urinary tract tuberculosis have a previous diagnosis of tuberculosis on abnormal imaging studies.

**8.1 Pathophysiology**

Hematogenous dissemination of the tubercle bacilli occurs from a primary focus most commonly the lung leading to the formation of "microscopic granulomas". In the event of an immunocompetent individual the granulomas heal or remain stable over time. If host immunity falls reactivation or reinfection occurs.

The medullary portion of the kidney is usually spared in the initial stages. The upper and lower poles of the kidney are more commonly affected with formation of cortical granulomas. These granulomas enlarge and coalesce extending to the renal pyramid. The lesions caseate and cavitate into the pelvicalyceal system leading to extensive papillary necrosis with formation of frank cavities. This leads to destruction of the renal parenchyma. The granulomas can also rupture into the collecting system. Calcification however uncommon in the early stages, is the hallmark of every end-stage tuberculous kidney. In immunosuppressed individuals granulomas and caseation are less frequent. Tuberculosis of the kidney can also present as a well-circumscribed multi-septated cystic renal mass[1,9]

The pelvicalyceal system is also involved in the form of urothelial involvement of the renal pelvis, ureter and bladder. Single or multiple calyces may be involved in one or both kidneys. In advanced disease there occurs parenchymal loss by caseation , intra-renal scarring, stricture formation and calcification leading to destruction of all or part of the kidney.

Rupture of the bacilli into the interstitium can lead to isolated interstitial disease. This creates a diagnostic dilemma due to lack of pyuria and hematuria with falling glomerular filtration rate(GFR). Interstitial nephritis can also lead to renal failure.

Some of the known complications include extra renal spread of the disease to involve the perinephric and retroperitoneal areas. Fistula formation involving the gastrointestinal tract, skin, lymphatic vessels and thoracic cavity are also known complications. Some individuals with urinary tract tuberculosis can also develop secondary amyloidosis and squamous metaplasia which is a known risk factor for squamous carcinoma of the renal pelvis[9,10]

**8.2 Imaging of Urinary tract tuberculosis**

**8.2.1 Abdominal radiography**

Calcification is present in 24-44% of cases of urinary tract tuberculosis and every end-stage tuberculous kidney contains calcification. Early calcification appears as amorphous, granular or curvilinear radio opacities occurring within the renal parenchyma. Triangular ring-like calcifications are characteristic of papillary necrosis. "Putty kidney" represents calcified caseous tissue which appears very homogeneous and only moderately dense on imaging . The "lobar pattern of calcification" is pathognomonic of tuberculosis and represents calcific rims outlining the periphery of distorted renal lobes. Calcification along the ureter when present is diagnostic of the disease[2,5,6,9]

The presence of "scarred calculi" which denote calculi in a scarred deformed renal pelvis and "hiked-up pelvis" indicating an upward-pointing renal pelvic calculi on radiographs are fairly specific features of renal tuberculosis.

**8.2.2 Intravenous urogram**

The earliest change on an intravenous urogram occurs in the minor calyces in the form of calyceal dilatation and mild loss of calyceal sharpness. The calyceal outline becomes irregular and fuzzy leading to the "moth-eaten" appearance in later stages. Early papillary necrosis may be the first detectable sign in some cases. Both forniceal and central papillary necrosis can occur. The occurrence of papillary necrosis results not only from ischemia but also as a result of direct tissue destruction. Medullary cavitation with communication to the collecting system also occurs[2,6,9]

In advanced stages extensive cavitation due to caseation of enlarging tuberculomas occur. Strictures involving the calyceal neck, infundibulum or renal pelvis may occur. Hydronephrosis with irregular margins & filling defects secondary to obstruction can also be demonstrated on intravenous urograms . "Phantom calyx" indicating completely stenosed infundibulum or calyx resulting in failure of contrast excretion by the involved renal parenchyma is a known imaging feature. Healed advanced disease can manifest as parenchymal scars leading to renal architectural distortion.

Progressive granulomatous destruction with obstructive uropathy leading to a non functional kidney is considered typical of end-stage renal tuberculosis. The kidney can be enlarged in the caseo-cavernous type or shrunken in the fibrotic type where calcification is common. Tuberculous pyocalicosis, parenchymal abscesses or pyonephrosis can also occur in advanced disease. Perinephric and psoas abscess with fistula formation with adjacent viscera and tissues are common complications of advanced disease. "Pyelo-lymphatic backflow" although seldom occurs is a useful pointer toward renal tuberculosis[6,9]

**8.2.3 Ultrasonography**

A normal sonogram in the presence of a non-functioning kidney is typical of renal tuberculosis. USG is less sensitive than IVU or CT in the evaluation of renal tuberculosis. The most frequently encountered sonographic parenchymal abnormality is the formation of parenchymal granulomas. These can be small 5-15 mm lesions that can appear echogenic or hypoechoic with an echogenic border. Larger lesions greater than 15 mm generally have mixed echogenicity and poorly defined borders. Cavitation and/or calcification can be noted[3,6,9]

Papillary involvement can occur in the form of an echogenic non-shadowing medullary mass in close proximity to the calyces. This produces a cavitatory lesion that communicates with a calyx. Focal caliectasis resulting from infundibular stenosis is a fairly specific sign of renal tuberculosis. Diffuse uneven caliectasis without renal pelvic dilatation accompanied by urothelial thickening is a good indicator of renal TB. The renal size is generally maintained[6,9]

Renal abscess with perinephric/psoas involvement can occur in advanced disease. The lobar pattern of caseation when seen is a sensitive indicator of tuberculosis. Calcification can be identified on ultrasonography. However, sonography is unable to differentiate between the various types of calcifications. Faint or early ureteral calcification may be missed on ultrasonography.

**8.2.4 Computed tomography**

CT aids in the diagnosis of renal tuberculosis. It also helps to assess the severity of the disease process in terms of loss of renal function[5,6,9]. The currently available MDCT scanners provide superior cross sectional images. CT has the following advantages over conventional imaging and utrasonography. It does not require bowel preparation. It directly visualizes the renal parenchyma irrespective of renal function and assesses the extrarenal spread of the disease. CT is the most sensitive modality for identifying renal calcification(Figure 25,26) Post contrast MDCT allows dynamic assessment of the kidney in different phases of excretion[6,9]

Tuberculous granulomas occur as solid masses with minimal enhancement usually accompanied by collecting system changes. Rarely, a well-circumscribed cystic mass with enhancing septations can be the imaging feature. "Lobar pattern of caseation"(Figure27) as mentioned earlier is also demonstrated on CT and is considered characteristic of tuberculosis. Multiple cavities with thinning of the adjacent cortex can occur(Figure 28) Focal areas of hypoperfusion due to localized tissue edema and vasoconstriction similar to acute pyelonephritis due to other causes can occur[6,9,10]

Focal or diffuse cortical scarring seen located overlying a deformed calyx or independent of the calyces occurs in advanced disease. Calcification varies in appearance depending upon the stage and severity of the disease and is the hallmark of end stage disease. Calcifications also occur in the clinical setting of *Mycobacterium avium-intracellulare* infections, however the calcification occurs in the acute rather than the chronic stage of disease[9]

Pelvicalyceal system involvement in the initial stages occurs in the form of papillary necrosis or minor calyceal deformities. Focal or diffuse "uneven caliectasis" unaccompanied by renal pelvic dilatation is a sensitive indicator of the disease. Urothelial thickening with multifocal strictures can also be demonstrated(Figure 29,30,31,32) "Daisy flower" appearance indicating a small and fibrosed renal pelvis accompanied by calcification is a described sign of the disease seen in advanced disease[9,10]

CT is also useful to assess the extrarenal extension of the disease namely perinephric and psoas muscle extension, adrenal involvement, retroperitoneal collections, fibrosis and subcutaneous collections. CT can also demonstrate the involvement of the prostate, seminal vesicle and spine. Fistulas to various sites are not uncommon and can be demonstrated on CT. Fistulas involving the kidney may communicate with the gastrointestinal tract, skin, blood vessels, lymphatics and rarely with the thoracic cavity[9]

**8.2.5 Magnetic Resonance Imaging**

MRI provides morphological characterization of the kidneys as well as excellent delineation of the ureters. It is of particular importance in children, pregnant women and in those patients where ionizing radiation or iodinated contrast is contraindicated. MR urography (MRU) comprises an evolving technique for evaluation of the urinary tract. Both static-fluid (non-contrast, heavily T2W sequences) and excretory MRU can be combined with conventional MRI for comprehensive evaluation of the urinary tract[9,10]

Renal parenchymal involvement in the form of localized tissue edema and vasoconstriction caused by active inflammation results in focal hypoperfusion as seen on contrast-enhanced MR. Tuberculous involvement of the kidney in the form of a TB granuloma is seen as a solid mass of variable size. The smaller lesions usually appear hypointense on both T1 and T2 weighted images. The larger nodules may reveal central hyperintensity on T2 weighted images. Rarely single or multiple parenchymal nodular lesions mimicking a renal neoplasm can be noted and are referred to as the 'pseudo-tumoral' type. Cavities(Figure 33), strictures and extrarenal spread of the disease can also be demonstrated on MR imaging.

Diffusion-weighted MR imaging (DWI) has been gaining importance in view of demonstrating renal fibrosis. An apparent diffusion coefficient (ADC) decrease in renal fibrosis was associated with an increased number of cells (including fibroblasts) and hence it has been suggested that ADC has the potential to serve as a sensitive non-invasive biomarker of renal fibrosis. This could be useful when applied to evaluating parenchymal fibrosis in the various stages of renal TB[9,10]

## IX. Fungal Infection

The individuals susceptible to the condition include those with diabetes mellitus, chronic indwelling catheter, malignancy, steroid therapy, post transplant and IV drug abuse. The most common organism affecting the urinary tract is *Candida albicans* . Renal parenchymal involvement is manifested by small parenchymal abscesss, perinephric extension and invasion of collecting system ultimately resulting in fungal ball[2,5,6]

On sonogram the lesions appear as micro abscesses which are small hypoechoeic cortical lesions. Fungal balls are mobile and appear echogenic, nonshadowing within the collecting system(Figure34) and may cause obstruction and hydronephrosis[2,3,6]

## X. Renal Disease Associated With HIV/AIDS

Renal disease is a common complication in patients with HIV/AIDS. It is often related to primary infection of the kidney or secondary to side effects of anti retroviral therapy **.** The urinary tract infections in these patients include pyelonephritis**,** renal abscesses and cystitis with imaging features similar to non HIV individuals[4] The presence of diffuse renal calcifications may suggest the possibility of disseminated *P.jiroveci, CMV or M. avium-intracellulare infections.*

### 10.1 HIV Associated Nephropathy (HIVAN)

HIVAN is the most common cause of chronic kidney disease in HIV positive individuals. The histologic hallmark of HIVAN is focal segmental glomerulosclerosis. The other causes of nephropathy in HIV patients include HIV immune complex disease and HIV thrombotic microangiopathy. However the definitive diagnosis of HIVAN requires renal biopsy[11]

A fairly specific and probably the most common sign of HIVAN on imaging is increased cortical echogenicity(Figure 35) Other imaging characteristics include decreased corticomedullary differentiation, decreased renal sinus fat and enlarged renal size with globular-appearing kidneys.

## XI. Figures

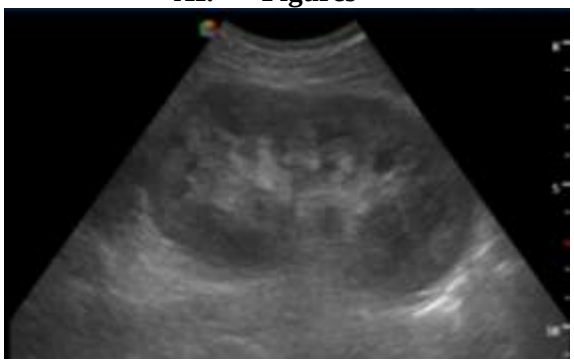

Figure 1 Transverse Sonogram of a case of acute pyelonephritis revealing enlarged kidney with loss of corticomedullary differentiation

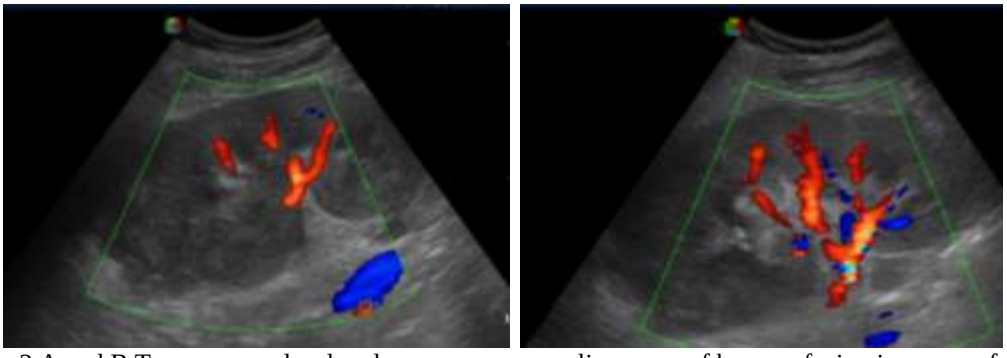

Figure 2 A and B Transverse color doppler sonogram revealing areas of hypoperfusion in a case of acute pyelonephritis

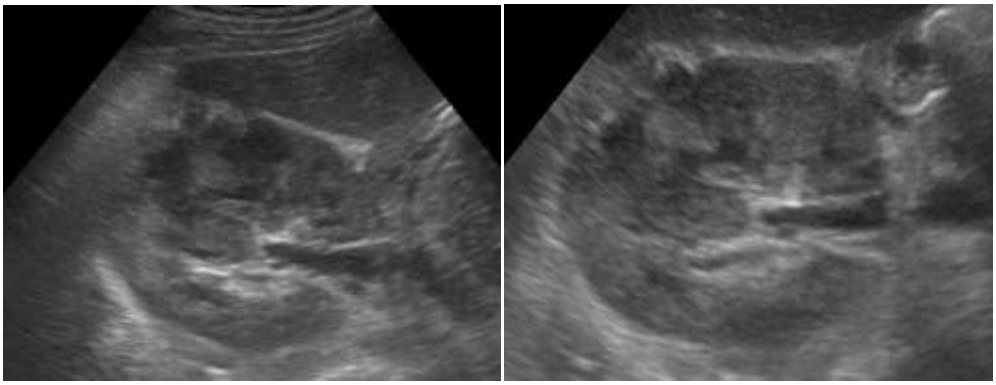

Figure 3 A and B Longitudinal Sonogram in a case of Acute Pyelonephritis revealing areas of Papillary necrosis

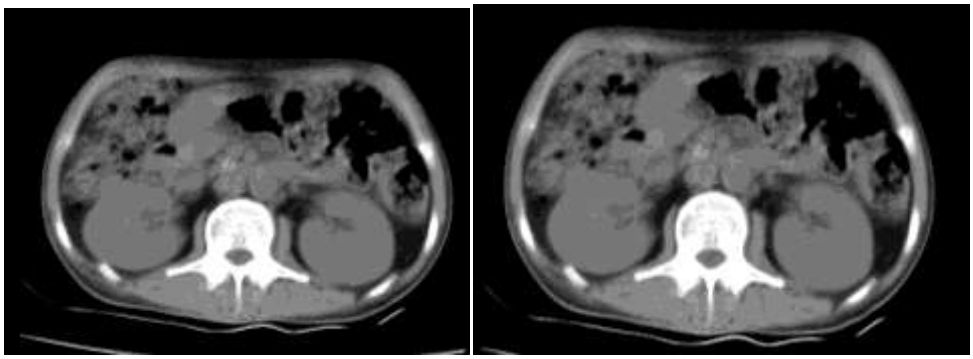

Figure 4 A and B Plain Computed tomography axial images in a case of Acute Pyelonephritis revealing bilateral enlarged kidneys with compressed sinus fat

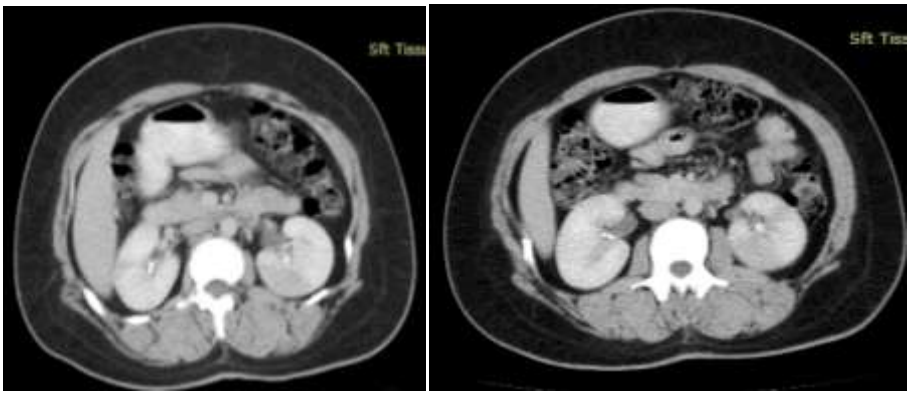

Figure 5 A and B Post Contrast Computed tomography axial images in a case of Acute Pyelonephritis revealing the "Striated Nephrogram"

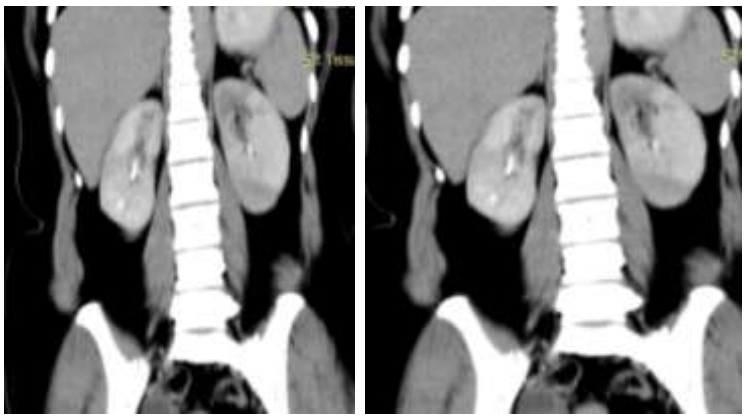

Figure 6 A and B Post Contrast Computed Tomography coronal images in a case of Acute Pyelonephritis revealing the "Striated Nephrogram"

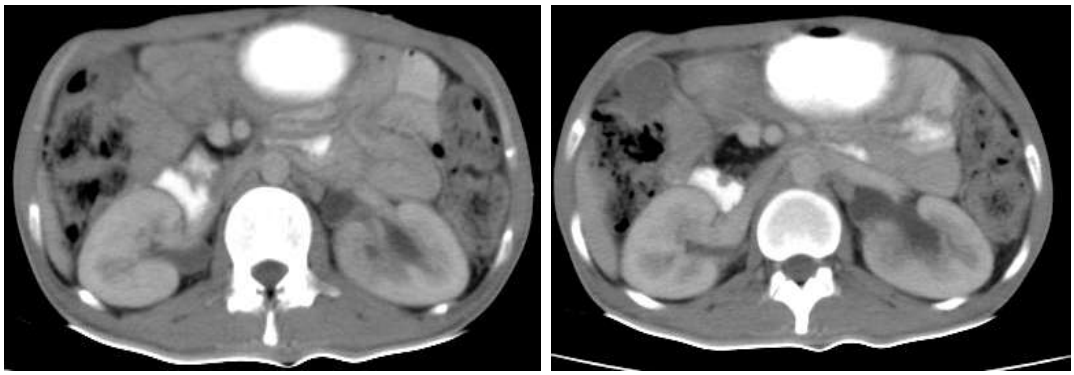

Figure 7 A and B Post Contrast Computed Tomography axial images in a case of Acute Papillary Necrosis revealing a necrotic papilla in the midpole of left kidney

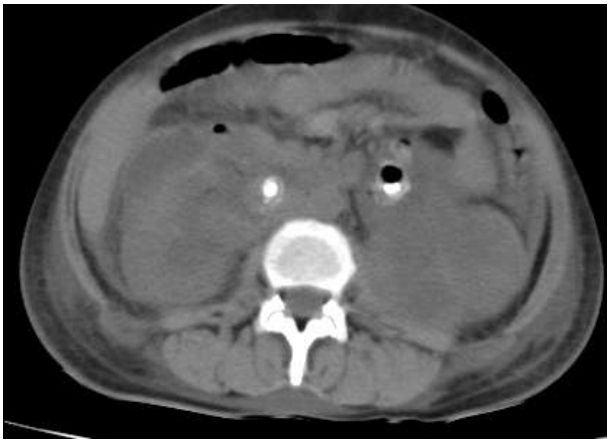

Figure 8 A and B Post Contrast Computed Tomography axial image in a case of Bilateral acute pyelonephritis with obstruction showing bilateral enlarged kidneys with perinephric stranding and pelvic calculus causing obstruction and dilatation of the pelvicalyceal system

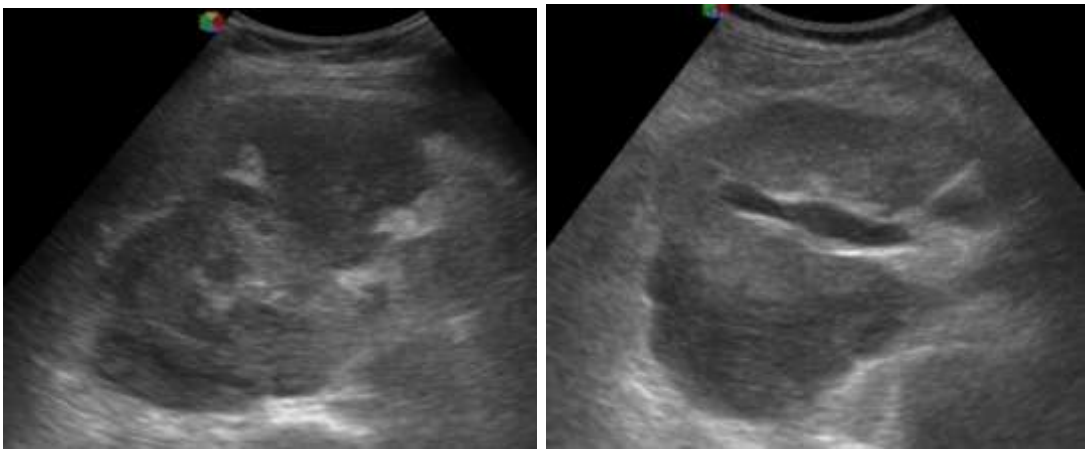

Figure 9 A and B Transverse sonogram in a case of Right Renal Abscess revealing hypoechoic areas in the mid and lower pole of the right kidney with perinephric extension

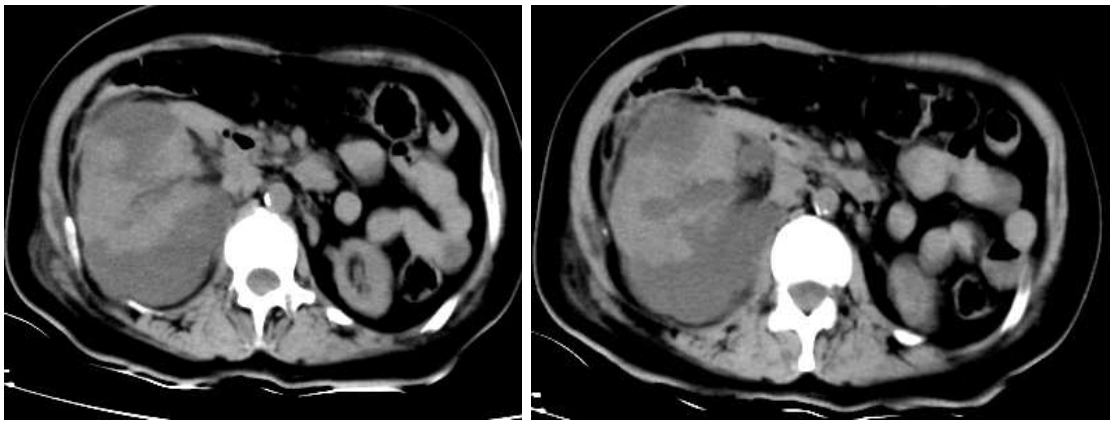

Figure 10 A and B. Plain Computed Tomography axial images in a case of Right Renal Abscess revealing hypodense areas in the mid and lower pole of the right kidney with perinephric extension stranding

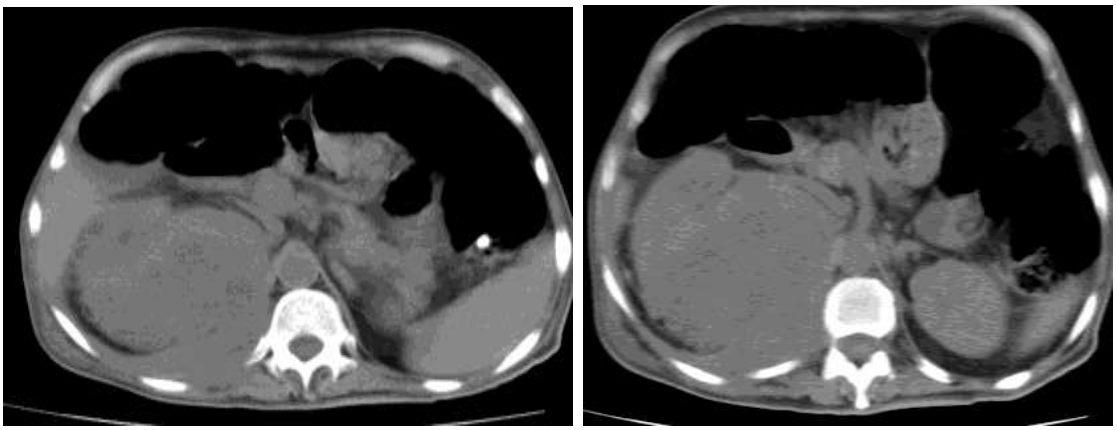

Figure 11 A and B Plain Computed Tomography axial images in a case of Right Renal and Psoas Abscess revealing hypodense areas in the lower pole of the right kidney with extension to the ipsilateral psoas muscle

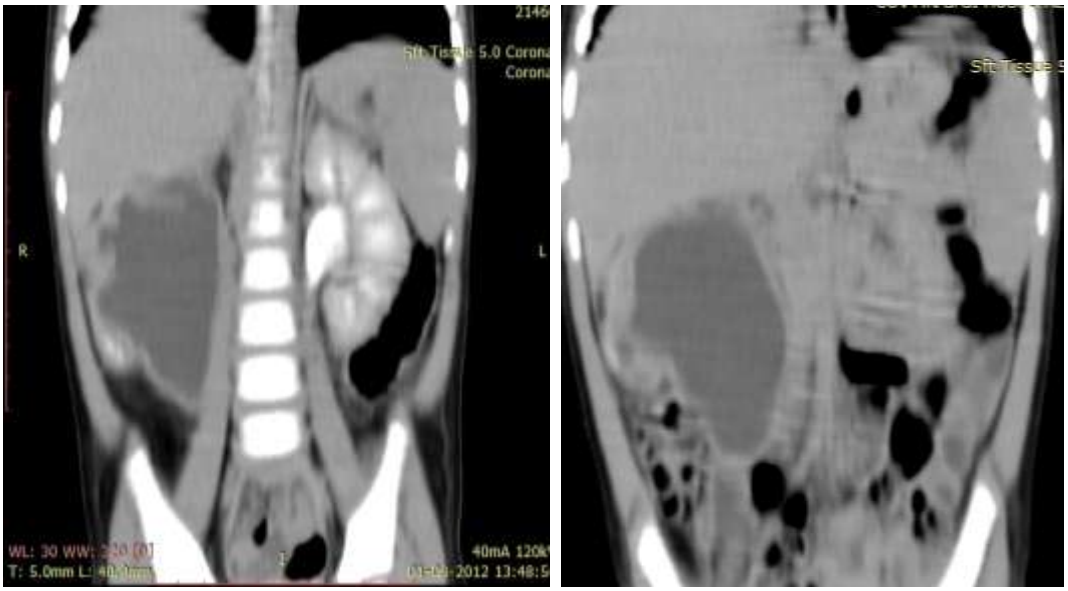


Figure 12 A and B Post Contrast Computed Tomography coronal images in a case of pyonephrosis revealing thickening of the renal pelvic wall with dilatation of the collecting system

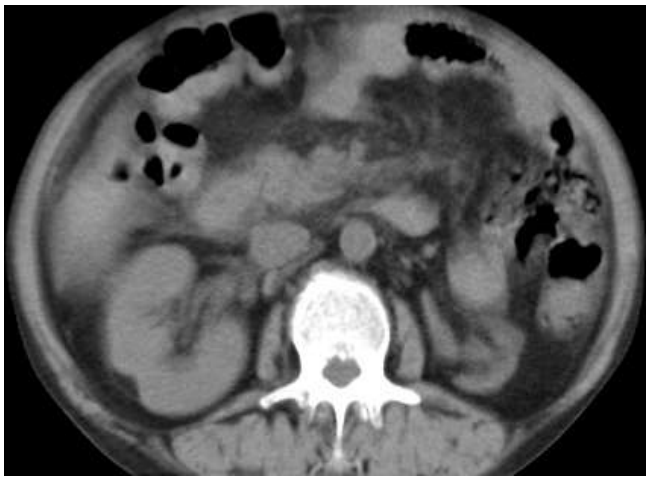

Figure 13 Plain Computed Tomography axial image in a case of bilateral Chronic pyelonephritis revealing an atrophied contracted left kidney with cortical scarring in the midpole of right kidney

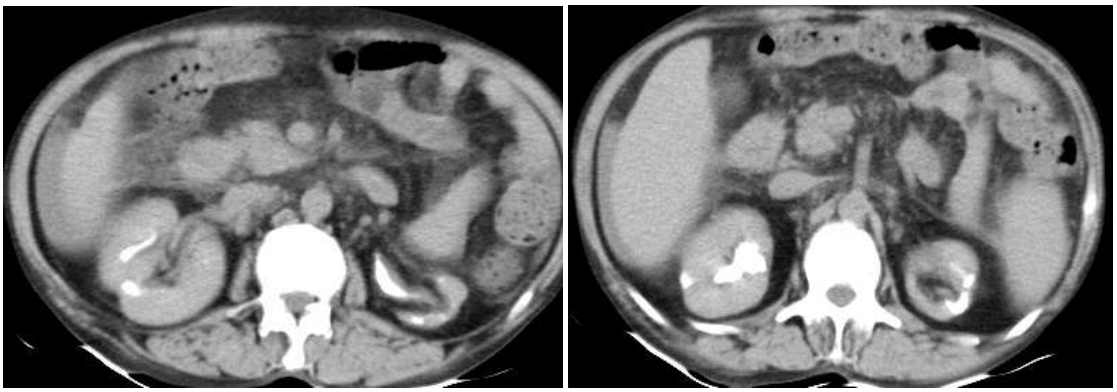

Figure 14 A and B Post contrast Computed Tomography axial images in a case of bilateral chronic pyelonephritis revealing an atrophied contracted left kidney with cortical scarring in the midpole of right kidney

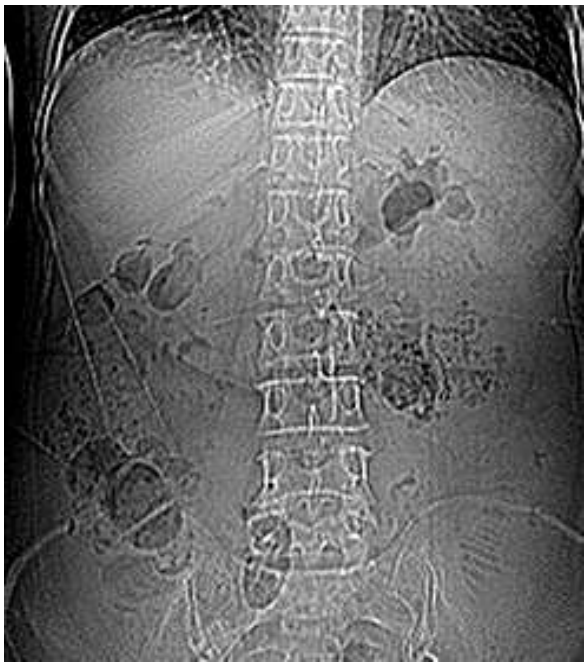

Figure 15 CT Scannogram of a patient with Emphysematous pyelonephritis of the left kidney revealing mottled gas in the left renal fossa

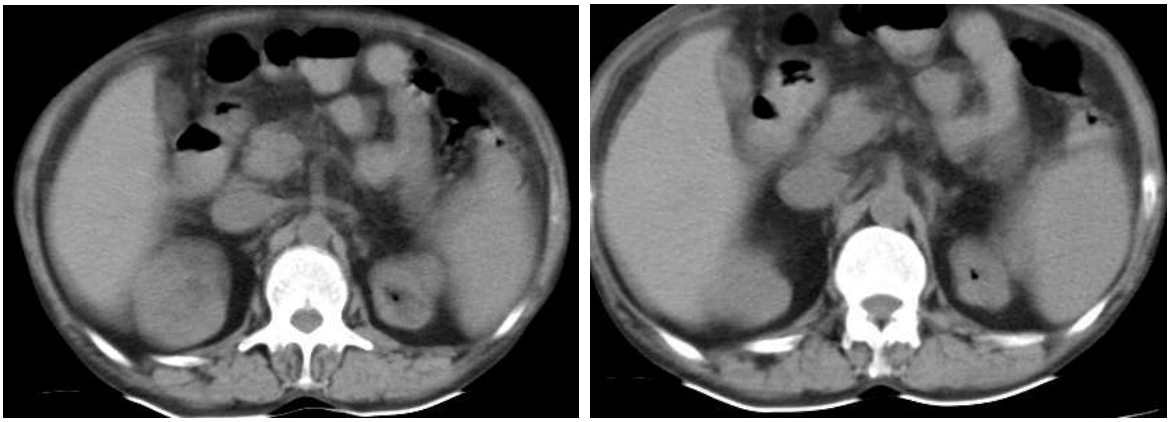

Figure 16 A and B Plain Computed Tomography axial images in a case of Class 1 Emphysematous pyelonephritis of the left kidney demonstrating air in the left collecting system (Emphysematous pyelitis)

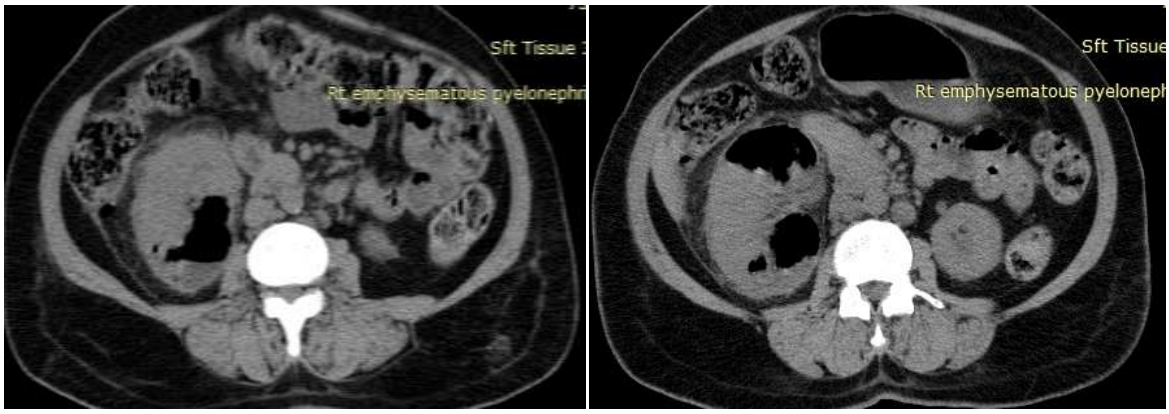


Figure 17 A and B Plain Computed Tomography axial images in a case of Class 2 Emphysematous pyelonephritis of the right kidney demonstrating air in the renal parenchyma

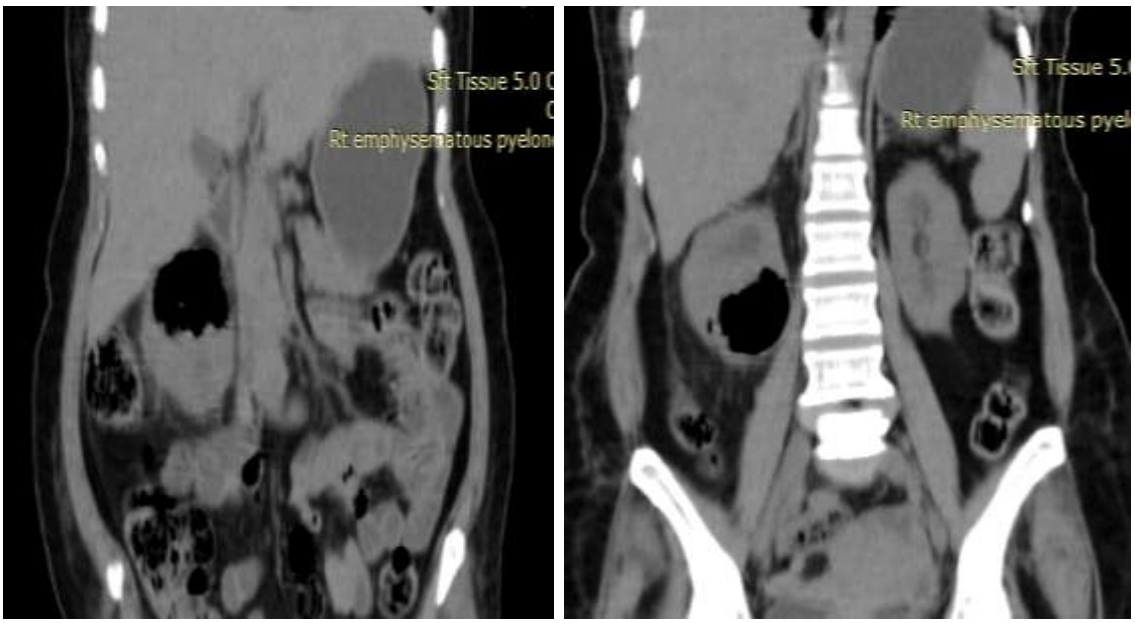


Figure 18 A and B Plain Computed Tomography coronal images in a case of Class 2 Emphysematous Pyelonephritis of the right kidney demonstrating air in the renal parenchyma

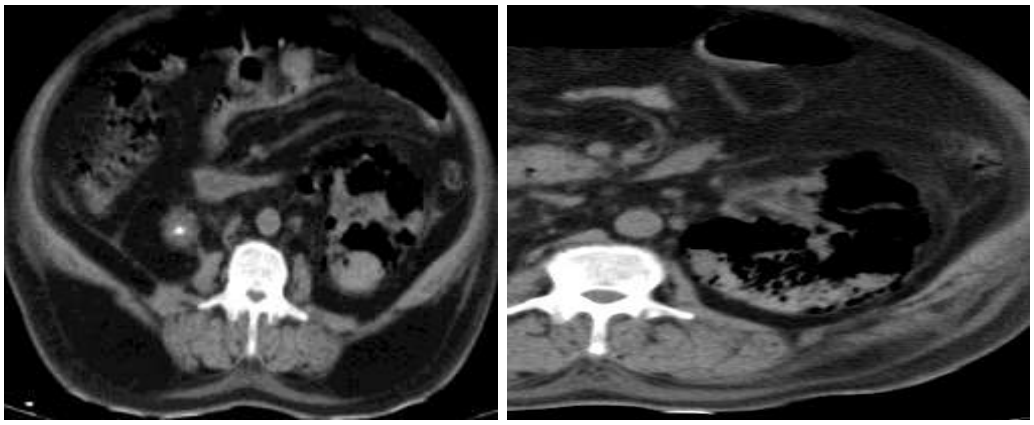

Figure 19 A and B Plain Computed Tomography axial images in a case of Class 3A Emphysematous pyelonephritis of the left kidney demonstrating air in the renal parenchyma with extension to the perinephric space

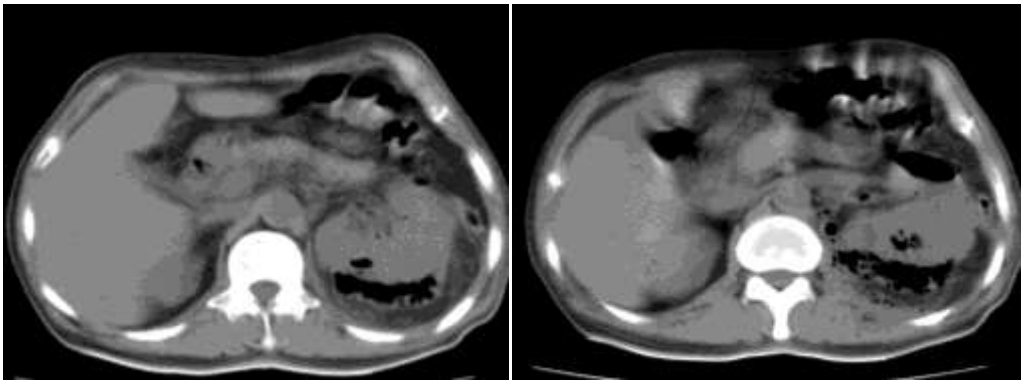

Figure 20 A and B Plain Computed Tomography axial images in a case of Class 3B Emphysematous pyelonephritis of the left kidney demonstrating air in the renal parenchyma with extension to the paranephric space

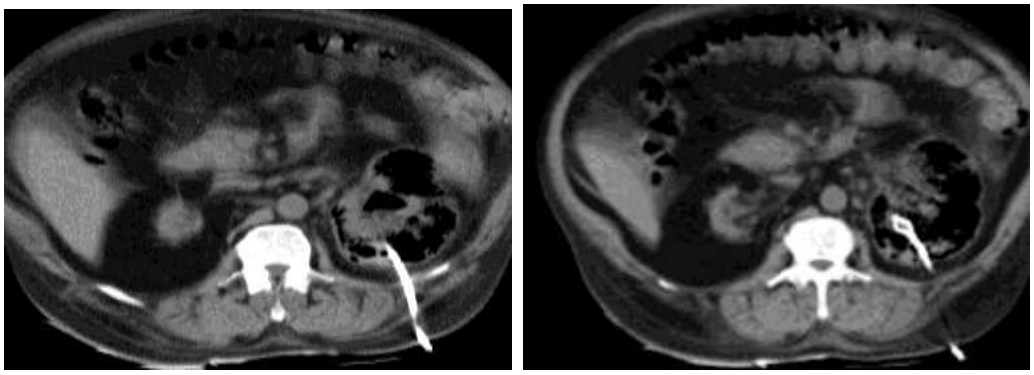

Figure 21 A and B Plain Computed Tomography axial images in a case of Emphysematous pyelonephritis of the left kidney post Percutaneous Nephrostomy (PCN) demonstrating air in the renal parenchyma with the drainage tube in situ in the left kidney

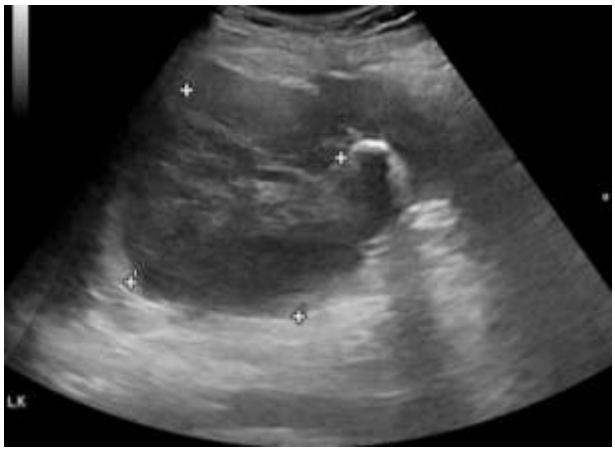

Figure 22 Transverse Sonogram in a case of Xanthogranulomatous Pyelonephritis revealing an enlarged kidney with loss of normal contour with a renal pelvis calculus with shadowing

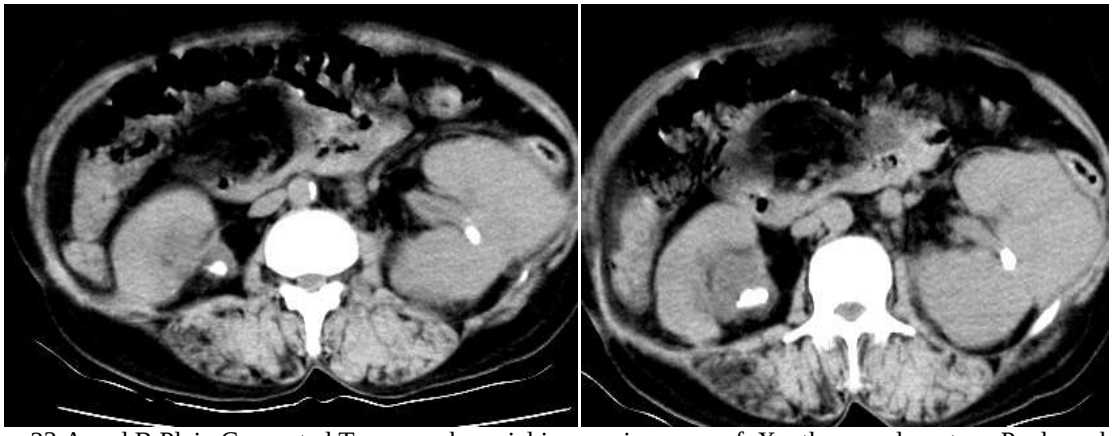

Figure 23 A and B Plain Computed Tomography axial images in a case of Xanthogranulomatous Pyelonephritis of the left kidney demonstrating an enlarged left kidney with loss of normal contour with a contracted renal pelvis with a pelvic calculus and urothelial thickening with mildly dilated calyces

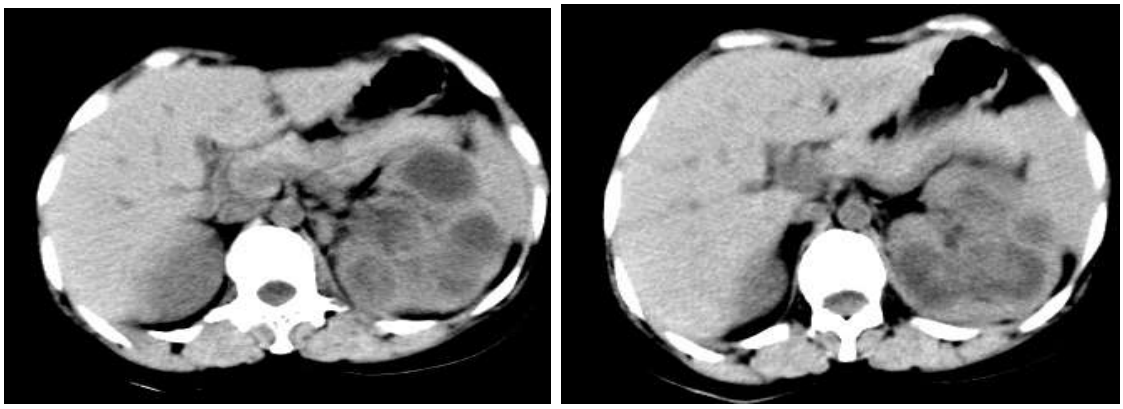

Figure 24 A and B Plain Computed Tomography axial images in a case of Xanthogranulomatous pyelonephritis of the left kidney demonstrating an enlarged left kidney with dilated calyces giving it a "multiloculated appearance" with no demonstrable calculus

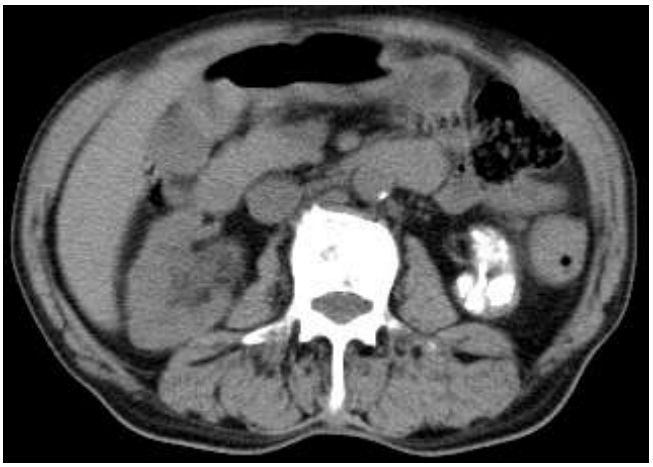

Figure 25 Plain Computed Tomography axial image in a case of end stage tuberculous left kidney demonstrating "lobar type of calcification"

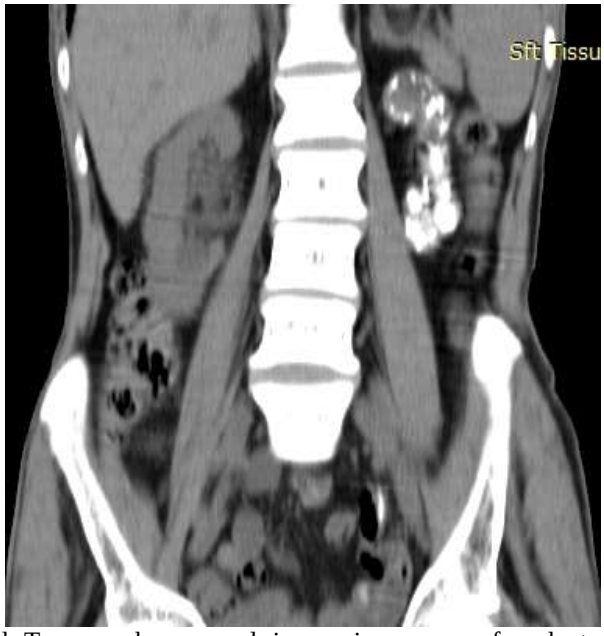


Figure 26 Plain Computed Tomography coronal image in a case of end stage tuberculous left kidney demonstrating "Lobar type of calcification"

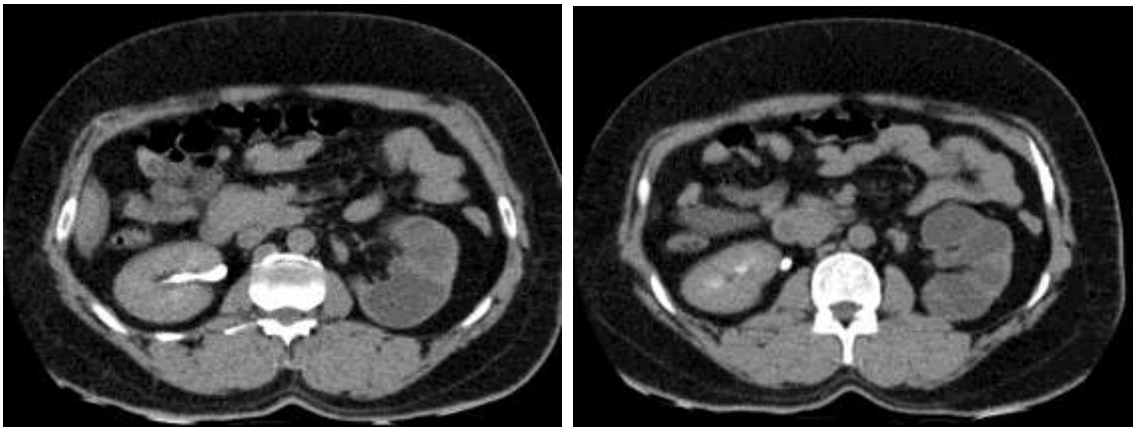

Figure 27 A and B Excretory phase of CT urogram axial images in a case of Tuberculous left kidney demonstrating Lobar Caseation with non functional left kidney and a normally excreting right kidney

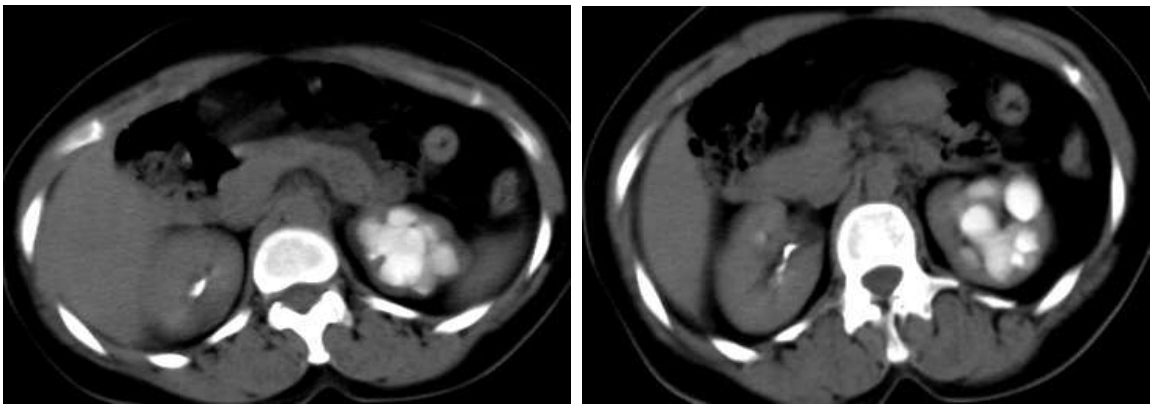

Figure 28 A and B Excretory phase of CT urogram axial images in a case of Tuberculous left kidney demonstrating multiple cavities

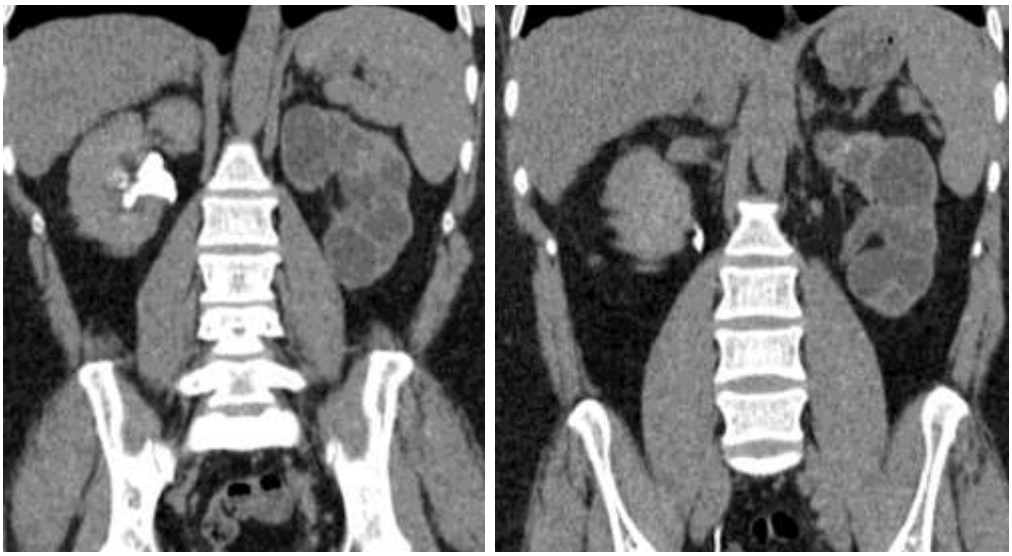

Figure 29 A and B Excretory phase of CT urogram coronal reconstructed images in a case of tuberculous left kidney demonstrating pelvic stricture with non functional left kidney and a normally excreting right kidney

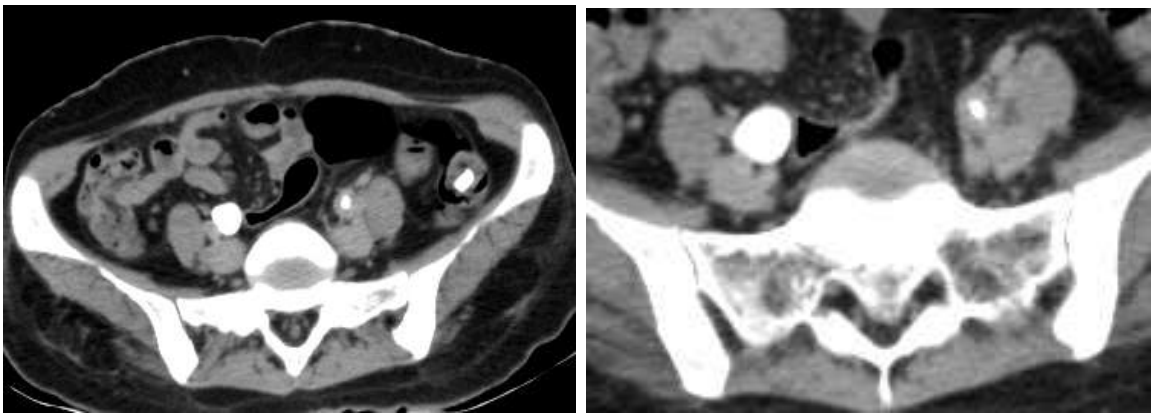

Figure 30 A and B Excretory phase of CT urogram axial images demonstrating a left ureteric stricture with dilated right ureter

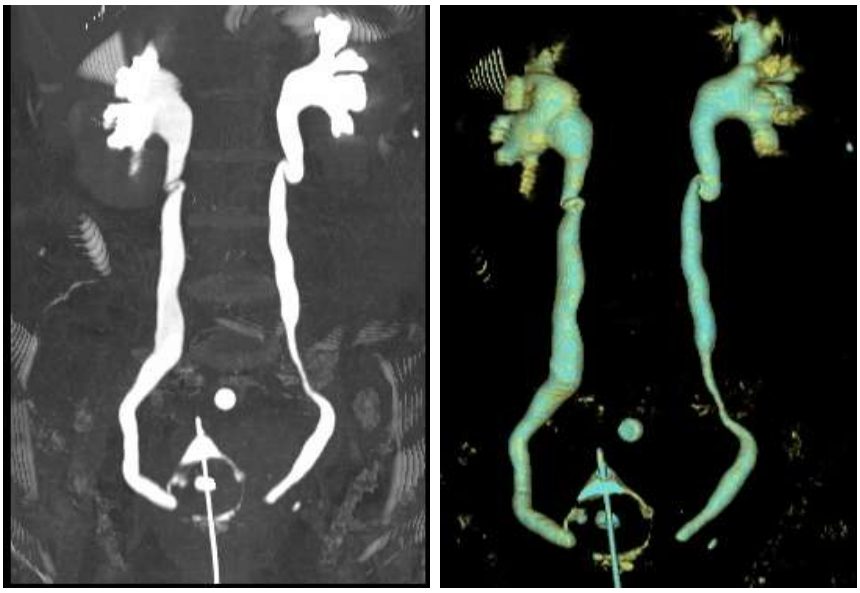

Figure 31 A Minimum Intensity Projection (MIP) coronal image and B 3D Reconstructed coronal image of left distal ureteric stricture with bilateral moderate dilatation of the collecting system

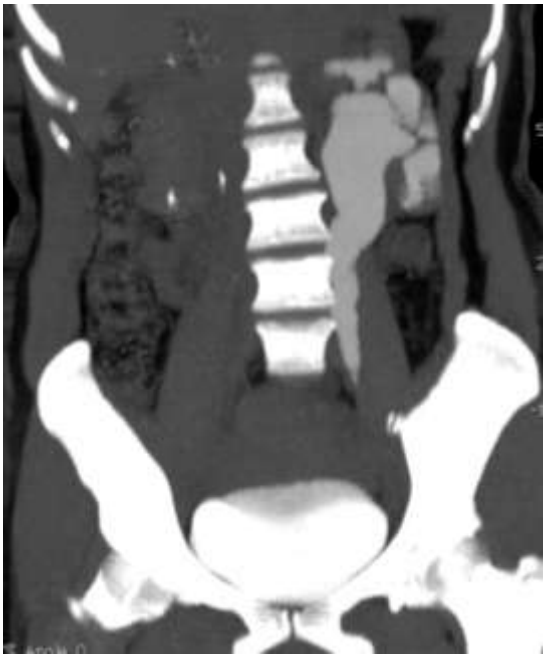

Figure 32 Excretory phase of CT Urogram coronal reconstructed images demonstrating moderate dilatation of the collecting system in the left kidney with multiple cavities and distal ureteric stricture

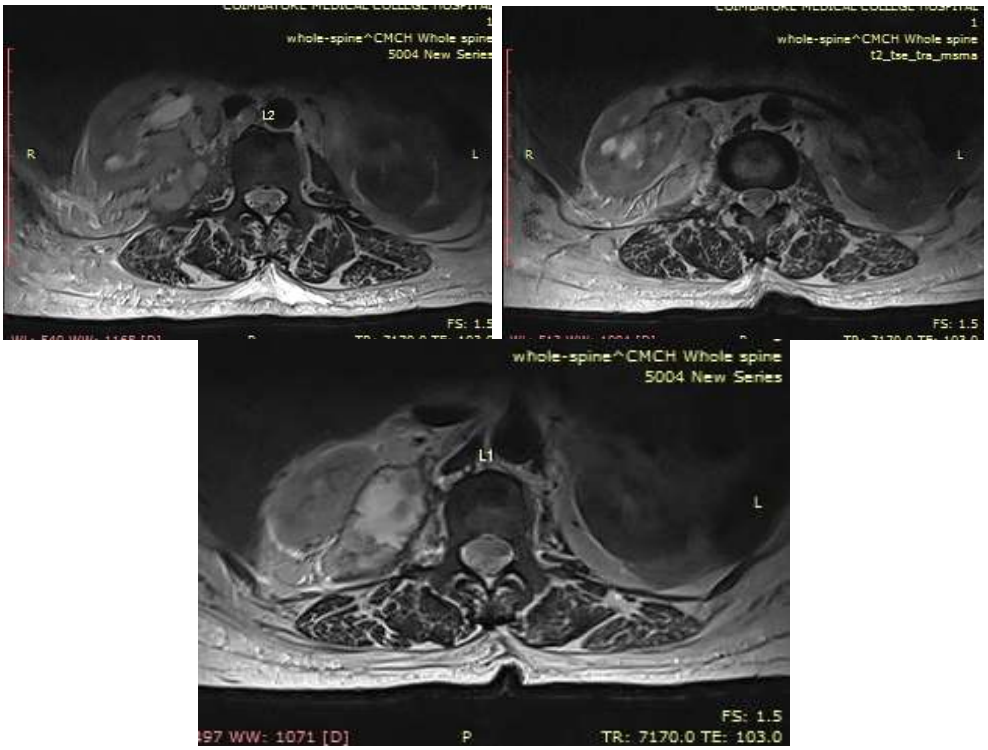


Figure 33 A,B,C T2 Weighted Turbo Spin Echo Sequence(TR 7170 TE 103) Axial images demonstrating dilatation of the right collecting system with multiple cavities suggestive of a possible tuberculous etiology

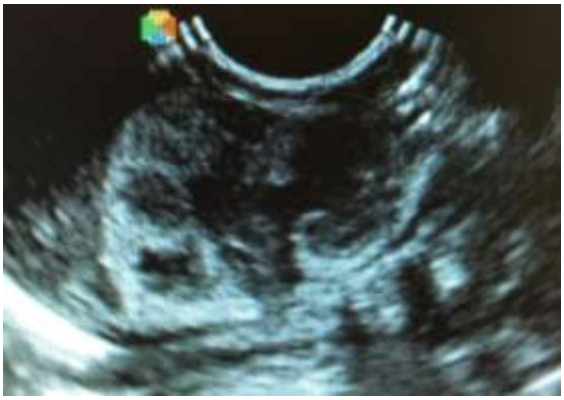

Figure 34 Transverse sonogram in a case of a fungal ball of the right kidney demonstrating an echogenic, non shadowing round lesion within the collecting system

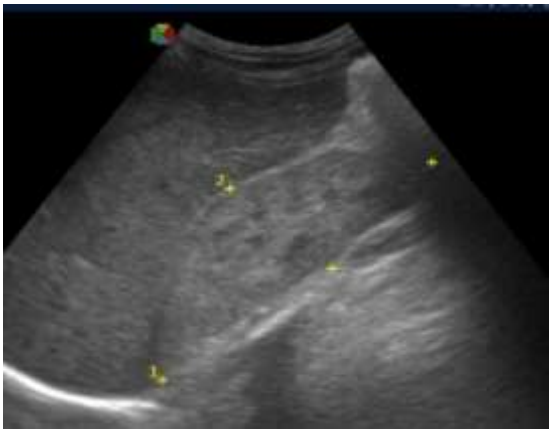

Figure 35 Transverse sonogram in a case of HIV associated nephropathy demonstrating increased cortical echogenicity

## XII. Conclusion

The pictorial essay emphasizes the potential advantages of various imaging modalities in the diagnosis of upper urinary tract infections. Ultrasonography remains the important preliminary imaging modality in evaluation of renal infections. It is also useful in follow-up and assessment of complications. Computed tomography is a sensitive and specific imaging modality in diagnosing early acute pyelonephritis, emphysematous pyelonephritis and chronic pyelonephritis. For early diagnosis of tuberculous infection a combined approach with a high degree of clinical suspicion is needed. For detecting fungal and HIV associated nephropathy, ultrasonography is a sensitive modality. MRI is very useful in characterization of tuberculous granuloma by their signal intensity and imaging pregnant patients.

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